

ENGINEERING GUIDE - 2

EG - 2

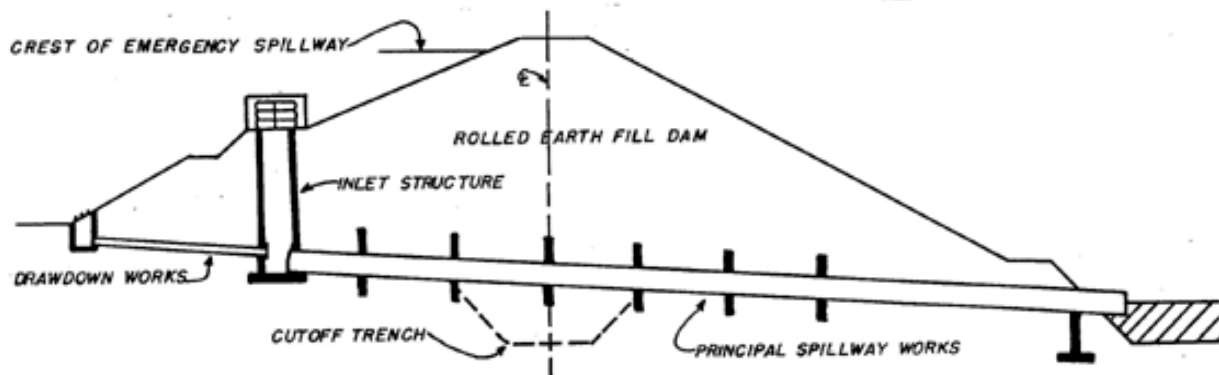
*Relating to Administrative Requirements
and Criteria for the Design of Earth Dams*

KANSAS STATE BOARD OF AGRICULTURE

DIVISION OF WATER RESOURCES

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TYPICAL EARTH DAM WITH DROP INLET



Cross section of dam on centerline of principal spillway

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FOREWORD

The legislature in 1929 enacted a law providing for regulation of the construction and maintenance of dams. Further legislation culminated in the present law enacted in 1978 with added emphasis on dam safety.

The provisions of K.S.A. 1982 Supp. 82a-301a provide “for the exclusive regulation of construction, operation and maintenance of all dams or other water obstructions by the state to the extent required for the protection of public safety...” by the Division of Water Resources, Kansas State Board of Agriculture and the Chief Engineer-Director. Federally-owned dams are exempt from the statute. The division independently analyzes and evaluates plans and specifications for constructing new dams and for enlarging, repairing, altering, or removing existing dams. The division must grant approval in writing before the owner may legally proceed with construction. The division conducts inspections and evaluates the dams and reservoirs to verify compliance with the approved plans and specifications and to assure that changes or unforeseen conditions are recognized and the design is modified as necessary.

INTRODUCTION

This guide is intended to illustrate the general minimum requirements of the division for the design and construction of earthfill dams. It is intended as an adjunct to Engineering Guide-1 (EG - 1), which contains hydrologic criteria relating to earth dams, hazard classes, spillway requirements, detention storage requirements and rainfall data, to assist the owner and his or her engineer in arriving at an acceptable design and adequate plans and specifications. This guide is not intended to constitute a text for the design and construction of embankment dams. Ultimate determinations by the division of the acceptability of design and adequacy of the plans and specifications must be made on a case by case basis.

In general, the guide is intended only for earthfill dams located in rural type settings with no unique foundation or embankment problems, and with low to high hazard potential for downstream damage should the structure breach. It may not, however, be applicable for the design of those dams to be constructed in urban areas.

This guide sets forth minimum acceptable standards and is not intended to preclude the owner or his engineer from developing new ideas or procedures that may enhance the utility or value of the dam. The division's objective is to achieve safe dams. This can be accomplished generally in the manner indicated in the guide, together with reasonable modifications appropriate to the problems at each individual dam site.

Inasmuch as the approval of an application to construct a dam does not grant the right to appropriate water, the applicant shall obtain a permit to appropriate water through the division for any beneficial, nondomestic use of water prior to obtaining a permit to construct a dam.

GENERAL

Plans and specifications for all dams which impound more than thirty acre-feet of water are required by law, K.S.A. 82a-301 through 305a, to be submitted for approval to the Chief Engineer-Director of the division. The Chief Engineer-Director's permit authorizing construction is to be issued prior to the commencement of construction. An application for permit to construct under the provisions of K.S.A. 82a-301 through 305a, accompanied by detailed plans and specifications for a dam shall be submitted to the Chief Engineer-Director, Division of Water Resources. Blank application forms will be furnished by the Chief Engineer-Director upon request.

All plans and specifications for dams except size 1 with an "a" hazard classification shall be designed by a licensed professional engineer, who is competent in dam design and construction. A minimum of two sets of plans and specifications should be submitted with the application. The plans must be clearly legible prints of the original tracings, capable of reproduction. Upon favorable consideration of the plans and specifications for a project, one set will be returned to the applicant; the second set will be retained in the office of the Chief Engineer-Director. If additional approved sets of plans and specifications are desired by the applicant, the number required should be submitted for endorsement by the Chief Engineer-Director.

Under the provisions of K.S.A. 82a-405 to 409, landowners who lawfully construct dams which meet the statutory requirements of said statutes in connection with the erection and maintenance of one or more reservoirs are eligible for a reduction in assessed valuation of land contiguous to the dam or reservoir.

Property owners that desire an exemption from ad valorem taxes for the construction of a dam and reservoir with a capacity of thirty acre-feet or less, but otherwise meets the statutory

requirements of K.S.A. 82a-405, must submit a letter of application, plans and specifications to the Chief Engineer-Director for approval in accordance with the provisions of K.S.A. 82a-406.

Upon completion of the dam, application shall be made to the Chief Engineer-Director for certification of completion. With receipt of said application, a survey of the dam is made by division personnel to confirm whether the structure has been completed in accordance with the approved plans and specifications. County records are reviewed to determine land ownership in the vicinity of the dam and reservoir. Upon a determination the dam has been satisfactorily completed the Chief Engineer-Director shall issue a certificate of completion to the county in which the dam and reservoir is located giving detailed information of the capacity of the reservoir or any rights-of-way or easements granted in connection with the project.

DESIGN CRITERIA

The design criteria offered in this section relates primarily to the construction, modification or repair of dams of moderate size and of the class commonly built for farm ponds, recreational reservoirs and flood control structures normally located in a rural environment.

For an earthen structure to function satisfactorily for its designated purposes, the following criteria shall be included in the design:

1. The emergency spillway shall be designed and sized for non-eroding velocities with sufficient capacity to prevent overtopping of the dam.
2. The embankment material shall be placed in such a manner to ensure a stable structure with a satisfactory factor of safety.
3. Free passage of water from the reservoir through the foundation and structure shall not be allowed.
4. Both front and back slopes shall be sufficiently flat and protected so as to reduce erosion to a minimum and to allow for upkeep and maintenance.
5. When conditions exist within the foundation of the structure which allow seepage beneath the structure, measures shall be taken to reduce the hydrostatic pressure and control releases to prevent erosion of the embankment and foundation material.

In those cases where the proposed structure is to provide protection from floodwater damage to downstream agricultural and rural property, guidelines, in addition to those contained hereinafter, shall be followed as set forth in K.S.A. 82a-928 of the state water plan and EG-1.

Top Width. The minimum top width of the dam is shown in Table 1 unless slope stability analysis indicates lesser dimensions are acceptable. When the embankment top is to be used as a public road, the minimum width shall be 26 feet for two lanes of traffic. The use of guardrails and other safety measures will be dictated by the density of traffic and/or responsible road authority.

Table 1

<u>Height of Dam</u>	<u>Minimum Top Width</u>
(feet)	(feet)
less than 20	10
20 to 24.9	12
25 to 39.9	14
40 or greater	15

The top of the dam shall be sloped towards the reservoir, in order that rain which falls on it will drain off on the protected upstream side.

Allowance for Settlement. The amount of additional embankment material required for settlement will depend to a large degree upon the nature of the material used in the dam as well as the manner in which the material is placed. When a detailed soil mechanics report is not provided an allowance of ten percent of the height shall be made. This allowance should be provided by steeping the side slopes during construction and adding to the height of the embankment as needed.

Side Slopes. Side slopes of earth dams may vary with the construction materials used, but in all cases shall be designed to be stable and easily maintained. Soil mechanics and slope stability analyses are required on size 2, 3 and 4 "c" hazard dams, size 3 and 4 "b" hazard dams, and all size 4 "a" hazard dams. Where slope stability analysis is required, the factor of safety required shall be as shown in Table 2. These safety factors are based on a load condition of steady seepage with the water level in the reservoir at the crest of the principal spillway.

Table 2

<u>Size</u>	<u>Hazard Class</u>	<u>Factor of Safety</u>
4	a	1.4
3,4	b	1.5
2,3,4	c	1.5

Dams located in a direction which subjects the face of the structure to prevailing winds, with resulting wave action, will need additional protection. The protection may be in the form of flatter slopes or in the use of riprap. Grasses or vegetation adapted to fluctuation of water levels may also be used to provide some degree of protection. Table 3 provides a guide to the steepest allowable slopes.

Table 3

<u>Height of Dam</u> (feet)	<u>Allowable Slope</u>	
	Upstream	Downstream
less than 12	3:1	2:1
12 or more	3:1	2 1/2:1

Principal Spillway. A pipe outlet, or overflow discharge pipe, shall be placed through all dams, except where a rock or concrete emergency spillway is to be provided. The crest of the inlet or riser pipe shall be set sufficiently below the crest of the emergency spillway so as to comply with the following:

1. A minimum vertical distance as specified in Table 2 of EG-1 shall be provided in those dams built for non-flood detention purposes.
2. In structures designed for the protection of agricultural lands, there shall be sufficient storage provided to control the four percent chance storm runoff. In those structures which protect urban areas, there shall be sufficient storage provided to control the two percent chance storm as specified in K.S.A. 1982 Supp. 82a-928 and as defined in EG-1.

Drawdown Pipe. All dams shall be equipped with a suitable drawdown pipe, no smaller than four inches in diameter near original streambed elevation, through which inflows may be bypassed for downstream water rights or releases made from the reservoir unless the applicant can show that downstream conditions do not require the installation of such a pipe. If it is proposed to not install a drawdown pipe downstream landowners who may be affected shall be given an opportunity to comment on the proposed structure. The names and addresses of the riparian landowners for two miles downstream shall be furnished by the applicant. After downstream landowners have been given an opportunity to comment, the Chief Engineer-Director may require the installation of a suitable outlet pipe if such installation is found to be in the public interest.

An acceptable valve shall be installed in the line in an accessible location and in such a manner so as to prevent damage from freezing. Drawdown pipes may be incorporated in the principal spillway structure.

Water Supply Pipes. When a water supply pipe is installed through the dam for purposes of watering livestock and other domestic uses, it should be no less than 1 1/4 inches in diameter. Control mechanisms such as valves or gates should be installed to prevent damage from freezing, cattle movement, vandals, etc.

Cutoff Collars. All pipes through material subject to saturation within the earth embankment, regardless of their designated purposes, shall be fitted with watertight cutoff collars or other accepted means of controlling seepage. Such collars shall be of sufficient size and number so as to increase the length of the seepage path along the pipe by a least fifteen percent. Spacing between collars shall be 20 to 25 feet. When a single collar is to be used, it shall be placed on the pipe near the point where the centerline of the dam intersects the pipe. If two or more collars are to be installed, they shall generally be placed within the middle third of the pipe length. Generally, such collars should project a minimum of two feet beyond the outside of the pipe, regardless of pipe size, and should be no closer than two feet to a field joint.

Pipe Conduit. All pipe conduits under or through earthen embankments shall be capable of withstanding the external loading without buckling, cracking or in any manner becoming damaged or deformed so as to impede their original function. Pipe shall be impervious with joints and seams watertight.

Conduit shall be installed with sufficient slope to provide adequate drainage, usually 1% minimum. Cambering of the conduit shall be considered in the design. The discharge end of the conduit shall be extended a sufficient distance beyond the downstream toe of the dam to avoid erosion of embankment. The pipe shall be adequately supported where it extends beyond the embankment.

Properly designed concrete conduit shall be acceptable for all hazard class dams. Properly designed metal conduit shall be acceptable for hazard class a and b dams up to a maximum height of fill over the pipe of 25 feet. Metal conduit may be allowed for dams with an effective height up to 35 feet provided acceptable engineering calculations are submitted to the division showing the design of the conduit is adequate to meet all criteria. If a metal conduit is installed, a suitable protective coating shall be provided to prevent corrosion and provided the same anticipated life as the rest of the structure. Other materials may be considered in specific circumstances with supportive engineering data and manufacturer's information to justify its use.

Cutoff Trench. The purpose of a cutoff trench is to prevent seepage of water through the foundation of the dam. This seepage should be stopped by construction of a cutoff trench extending into a relatively impervious stratum, or combined with other seepage control, to provide a stable structure. Side slopes on the cutoff trench shall not be steeper than 1 to 1. The material used in backfilling the cutoff trench shall consist of the most impervious material available at the site and shall be homogeneous with the impervious zone within the embankment.

Emergency Spillway. Emergency spillways are to be provided for additional safety to the structure when runoff is greater than that which can be stored in the reservoir.

The positioning, profile and length are influenced by geologic and topographic characteristics of the site and are determined by acceptable reservoir floodrouting procedures of design storms as tabulated in Table No. 2 of EG-1. The cross-section dimensions, usually trapezoidal, are governed by hydraulic requirements. A discussion of acceptable hydrologic procedure is presented in EG-1. Provision shall be made for additional safety to the structure by providing freeboard above the maximum design stage ranging from one foot to three feet depending upon the hazard class of the structure as shown in Table No. 2 of EG-1.

Discharge from emergency spillway shall be so directed that flows return to the channel without causing erosion along the downstream toe of the dam. Emergency spillways proposed for the protection of earthen embankments shall be in full cut, if possible, to avoid flows against the constructed fill. The side slopes of the excavated channel in earth shall be no steeper than 3:1 of ease of maintenance. Where the site limitations prevent a full channel cut, a wing dike shall be provided to direct spillway flows away from the downstream toe of the dam.

The configuration of the entrance channel from the reservoir to the control section of the emergency spillway shall be a smooth transition to avoid turbulent flow over the spillway crest. The outlet channel of the emergency spillway shall convey flow to the channel below the structure with a minimum of erosion. The slope of the exit channel usually follows the configuration of the abutment, unless exit velocities are excessive. A flatter slope with a widening of the bottom width, should be reduce exit velocities to a level where erosion will not pose a problem. In cases of highly erodible soils it may be necessary to use other means of protection such as riprap, grouted rock or concrete paving to form the exit channel. Especially adapted grasses provide a stabilizing effect and reduce erosion in the exit channel. Detention storage can be increased to reduce the frequency and/or duration of use of the emergency spillway and thereby reduce erosion problems.